

WSDOT PAVEMENTS —

A 1995 STATUS REPORT

Why this report?

This report provides an overview of the state owned pavements maintained by the Washington State Department of Transportation (WSDOT). It provides information on the types of pavements used, how they deteriorate and are rehabilitated, and how they are managed.

The WSDOT route system will accommodate about 75 billion vehicle-kilometers of travel during 1995. This amount of travel represents vehicle operating costs of about \$23 billion to the traveling public. The WSDOT annual budget without the ferries, aviation, and state interest programs amounts to about \$900 million. This represents a WSDOT expenditure of about 1.2¢ per vehicle-kilometer traveled. As you can see, owning and maintaining the state's route system involves big numbers. Based on national averages, every person travels about 50 kilometers per day with over 80 percent of this travel via motor vehicles on highways.

Brief history of WSDOT route system

The origin of the WSDOT route system goes back to 1852 when the Legislature of the Oregon Territory established the first "official" road. This road (Byrds Mill Road) connected Puyallup to Tacoma then on to Steilacoom. The Washington Highway Department was created in 1905 by the state legislature, but until 1909, the maintenance of state roads was done by the counties.

It was not until about 1910 that road surfaces began to be paved. Paving was largely required by the advent of the automobile replacing horse-drawn vehicles.

In 1911, the Permanent Highway Act was passed by the legislature. Permanent highways were to be graded to widths of not less than 4.9 m and surfaced with crushed stone, gravel, or some other durable material for a width of not less than 3.6 m (equivalent to one lane-width today). Grades were not to exceed 5 percent whenever possible and in no case greater than 10 percent.

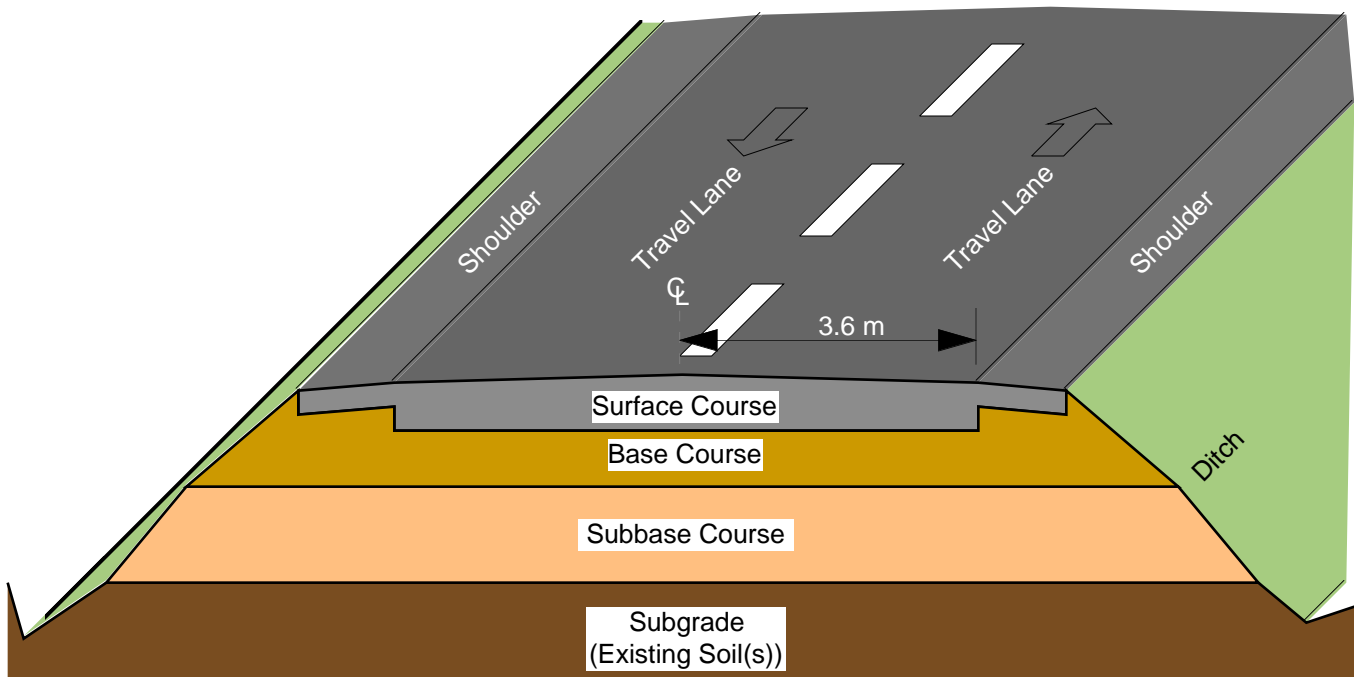
Apparently, the first portland cement pavement in Washington state was built in Lewis County in 1912. About this time, bituminous surfacings came into use as well. There is photographic evidence of early bituminous paving in Spokane in 1898.

The current pavement types in use by WSDOT largely came into use during the late 1940s and early 1950s.

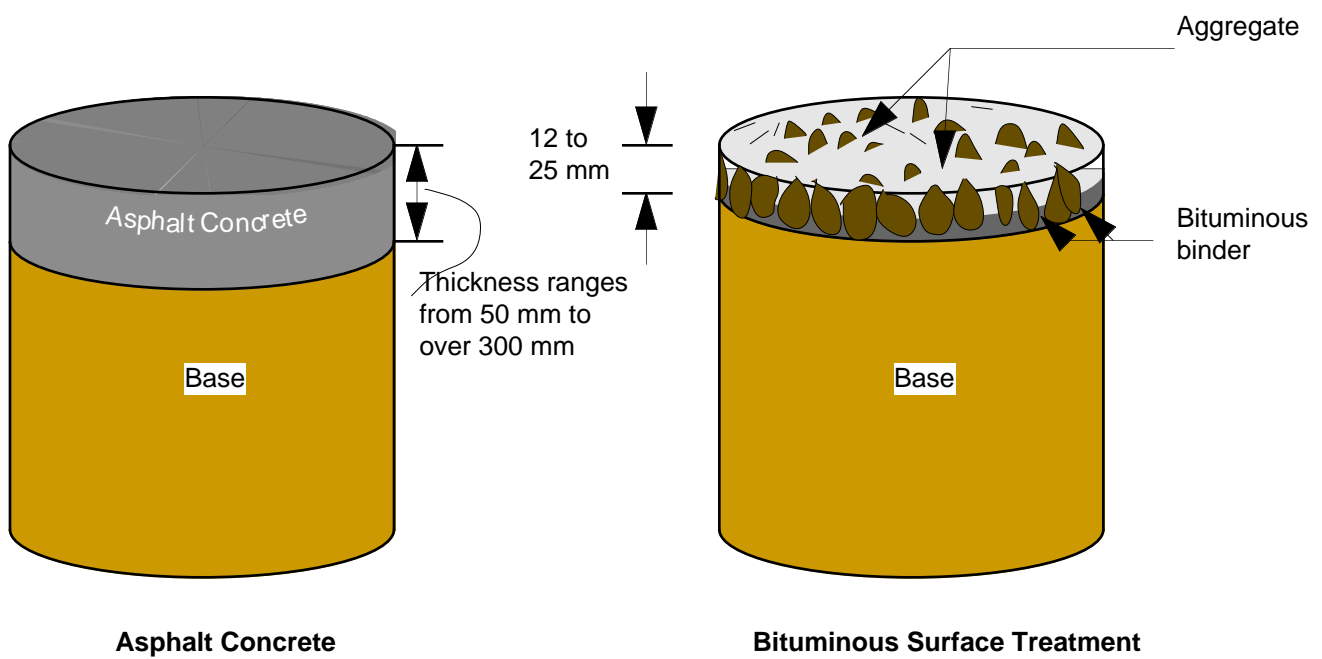
Types of pavements

Basically all hard surfaced pavement types can be categorized into two groups, flexible and rigid. Flexible pavements are those which are surfaced with bituminous (asphalt) materials in the surface (wearing) course. These can be either in the form of pavement surfaces such as bituminous surface treatment (BST) or asphalt concrete (AC). A BST surface is generally used on lower traffic volume roads and AC surfaces on higher traffic volume roads (refer to flexible pavement illustration). These types of pavements are called "flexible" since the pavement structure "bends" or deflects due to traffic loads. Further, the flexible pavement structure is generally composed of layers of materials which can accommodate this "flexing." On the other hand, rigid pavements are composed of a portland cement concrete (PCC) surface course (refer to rigid pavement illustration). Such pavements are substantially "stiffer" than flexible pavements due to the high stiffness of PCC. To accommodate and control cracking, which is a fundamental PCC characteristic, joints (weakened planes) are incorporated into the PCC slabs during initial construction. WSDOT typically spaces transverse joints about 3.6 to 4.6 m apart. On Interstate PCC pavements such as I-5 and I-90, these joints can become rough after 30 or so years of service. WSDOT corrects this problem by strengthening the joints with steel then grinding off the rough areas with diamond abrasive saws.

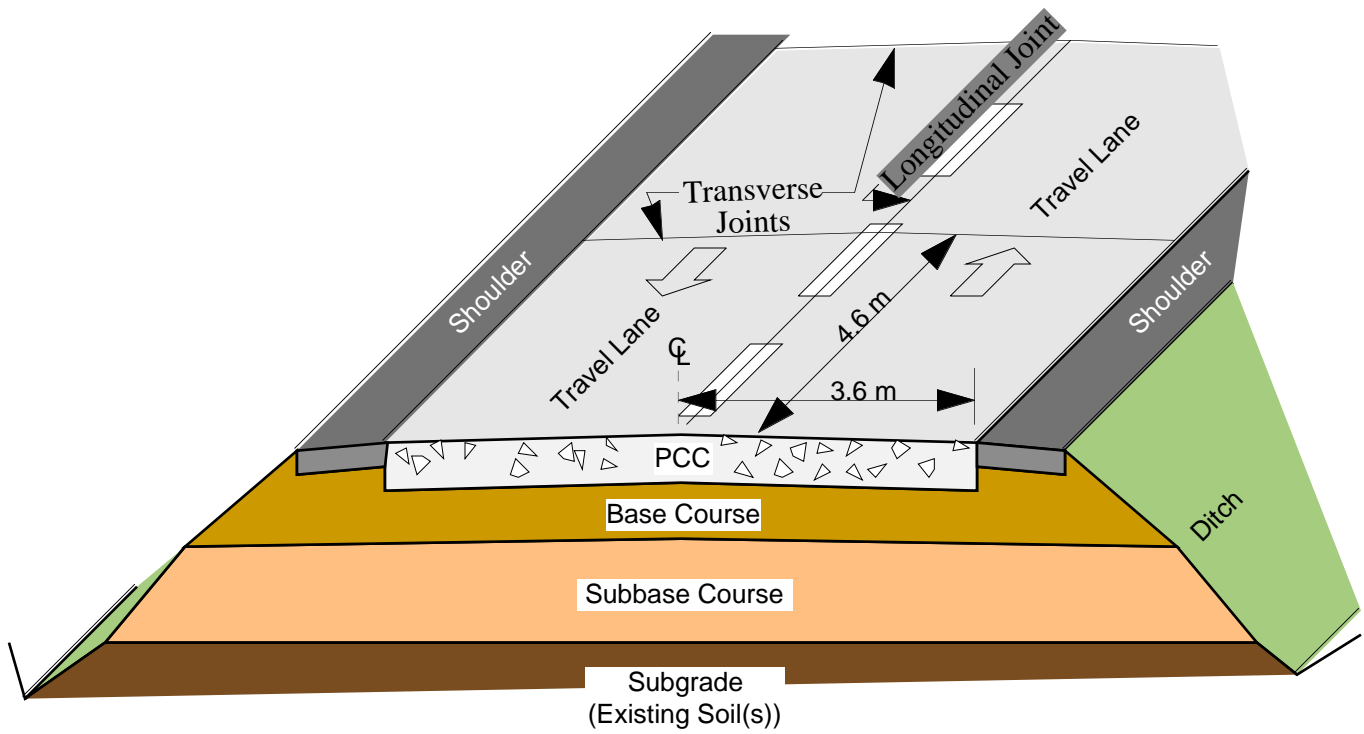
Typical Flexible Pavement Cross Section



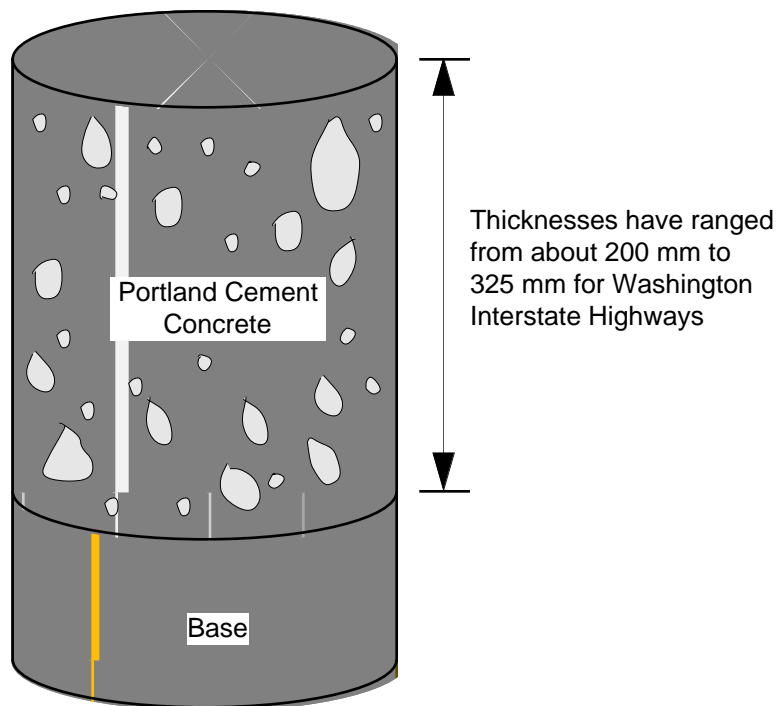
Types of Flexible Pavement Surface Courses



Typical Rigid Pavement Cross Section



PCC Surface Courses

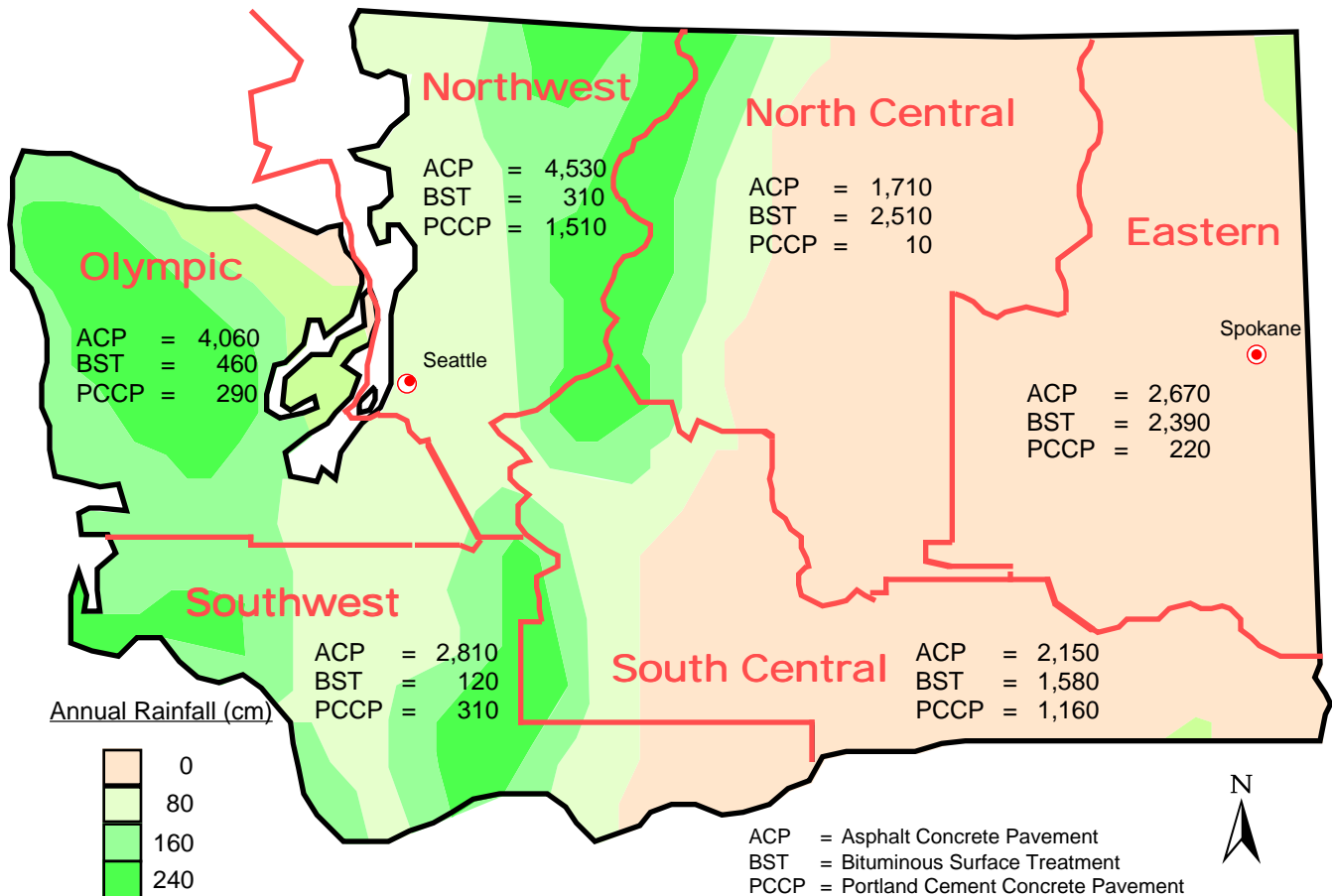


The WSDOT route system has about 29,000 lane-kilometers of pavements. A breakdown by pavement type includes

- ACP: 17,930 ln-km (62%)
- BST: 7,370 ln-km (26%)
- PCCP: 3,500 ln-km (12%)

Clearly the dominant surface type is asphalt concrete (62 percent of the total lane-kilometers) followed by bituminous surface treatments (26 percent) and portland cement concrete at 12 percent. Further, about 88 percent of the BST surfaced pavements are in the Eastern Washington Regions, along with 36 percent of the ACP and 40 percent of the PCCP. Specific Regional values are illustrated in the figure.

WSDOT Regional Lane-Kilometers



What causes WSDOT pavement to deteriorate?

There is a straightforward answer to the question, "What causes WSDOT pavements to deteriorate?" The primary two reasons are vehicles and the climate.

Vehicle-caused pavement damage can be separated into autos with studded tires and trucks (due to axle loads). Studded tires are largely responsible for the grooves one sees in some of our high traffic AC pavements. Further, after many years of wear, studded tires have even worn grooves in PCC slabs (particularly I-5 in the Seattle area and I-90 in Spokane). Trucks come into the picture via the loads placed on axles — the heavier the load, the more pavement damage. In fact, an approximate way to view this damage is called the fourth power law:

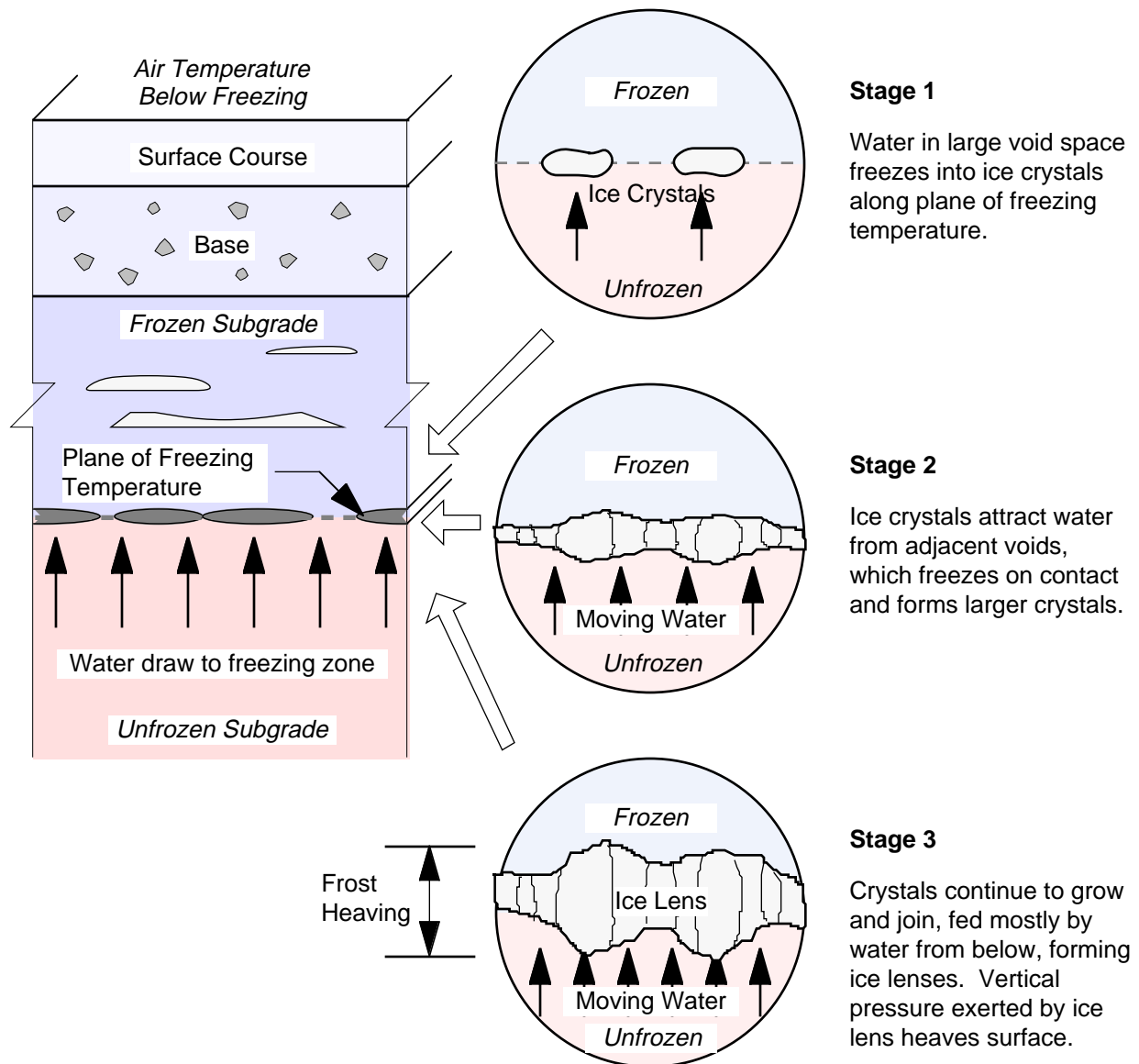
$$\text{pavement damage} \cong (\text{axle load ratio})^4$$

Thus, a truck axle loaded to 80 kN as compared to the same axle loaded to 40 kN would cause $\left(\frac{80 \text{ kN}}{40 \text{ kN}}\right)^4 = (2)^4 = 16$ times more damage for only twice the axle load. This is one fundamental reason why heavier trucks pay more for annual licensing fees. Pavement structures are designed to accommodate the expected truck traffic. Thus, more truck traffic results in thicker pavements.

The second major cause of pavement deterioration is related to climate effects. More specifically, it is the interaction of climate and traffic which can cause substantial pavement damage.

Climate has a profound effect on pavement performance in all northern states due to ground freezing during the winter months followed by thawing. The part of Washington state primarily affected by this process is east of the Cascade crest and thus includes the North Central, South Central, and Eastern Regions.

The freezing process can cause ice lenses to form underneath or even within the pavement structure. As illustrated in the figure, the freezing process penetrates into the ground beneath the pavement. This process can draw water into the soils beneath the pavement (or into the pavement structure). In fact, the freezing process can draw water from as deep as 10 m beneath the pavement surface. To add to this phenomenon, the depth of freezing is greater in those pavements which have snow plowing (snow being a good insulator reduces the depth of freeze).



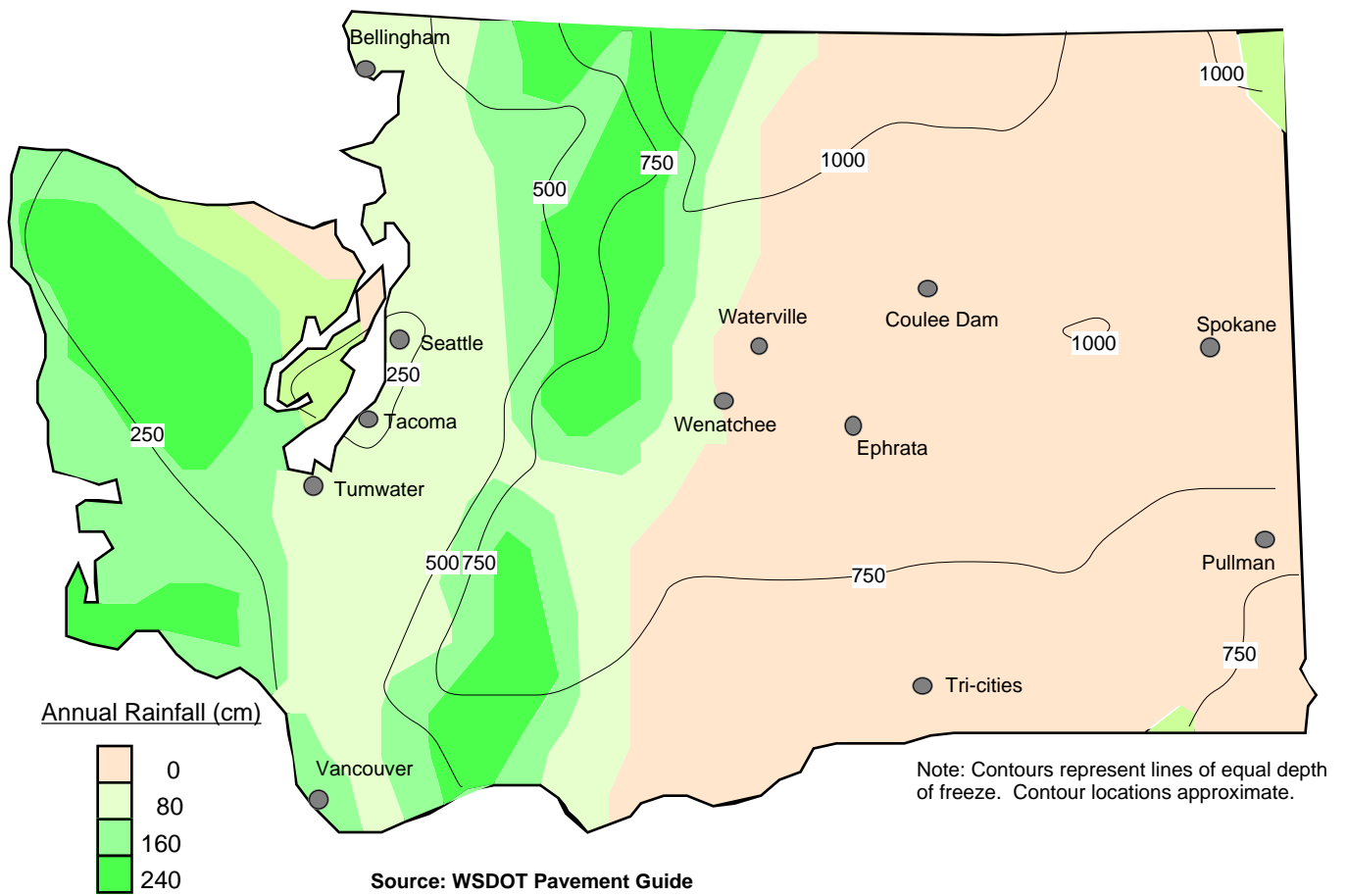
The freezing process can result in frost heaving due to creation of ice lenses. This can result in the pavement surface being heaved upward by a few millimeters to as much as one-half meter.

When this ice lensing occurs, the reverse process, thawing, is even worse for pavement performance. Thawing normally occurs from the top of the pavement downward. As the layers within and beneath the pavement thaw, the extra water that has resulted from the earlier freezing action is released, but it cannot drain because the subgrade soils below it are still frozen. This results in a temporary condition in which the upper portions of the subgrade soils and the pavement structure are fully saturated. This wet, weak condition can exist until all of the subgrade has thawed.

In the eastern part of Washington state, ground freezing usually starts during December and stops during February. By late February or early March, the thawing process begins. On some of WSDOT's low-volume, older roads, severe thawing and weakening results in restrictions on truck and bus traffic. These load restrictions can last as little as a few days and up to one month.

Both the freezing process, in general, and freeze-thaw cycles represent the single most critical climate effect which affects WSDOT pavements. Those areas which combine freezing with a ready supply of water are the most severe. Typical depths of ground freezing across Washington state are shown in the illustration. Depths of freeze which exceed the depth of the pavement structure are especially critical.

Typical Estimated Depths of Ground Freezing During a Severe Winter (inches)



Condition of the WSDOT route system

All inanimate objects subjected to repeated use, wear-and-tear or loading cycles will fail eventually — unless some type of maintenance or rehabilitation process is performed. This is true of pavements as it is for commercial jet aircraft, buses, bridges, automobiles, railroads, locomotives, and so on. Typical average ages for some of the nation's transportation elements include:

- automobiles: 8 years
- commercial jet aircraft: 18 years
- commuter rail vehicles: 17 years
- urban buses: 8 years

The oldest unrehabilitated pavement in the WSDOT route system is a short segment of SR 11 near Burlington, Washington. Built in 1921, this PCC pavement is 74 years old (however, it has not experienced any significant, heavy traffic for many years). More typically the average age of a flexible pavement surface course is about 8 years and a rigid pavement about 25 years (most of WSDOT's rigid pavements are on the Interstate system and these were mostly built during the 1960s and 1970s).

WSDOT manages the route system by monitoring all pavements to estimate when maintenance or rehabilitation activities are required. Four fundamental measures are used:

- pavement distress (such as cracking)
- wheelpath rutting
- roughness
- surface friction

Each measure will be briefly described.

Structural Condition

Overall pavement distress is termed Pavement Structural Condition (PSC) and is calculated separately for flexible and rigid pavements. The PSC has an upper limit of 100 (no distress) and a lower limit of 0 (extensive distress). The PSC is calculated based on the amount and severity of the following distress types:

- ***Flexible pavements***

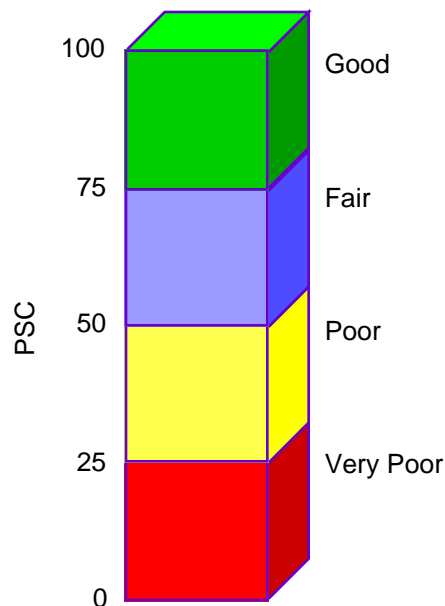
- fatigue cracking (cracks due to repeated load cycles)
- longitudinal cracking
- transverse cracking
- patching

- ***Rigid pavements***

- slab cracking
- joint and crack spalling
- pumping and blowing
- faulting and settlement
- patching
- raveling and scaling

The PSC can be described by four broad pavement condition categories:

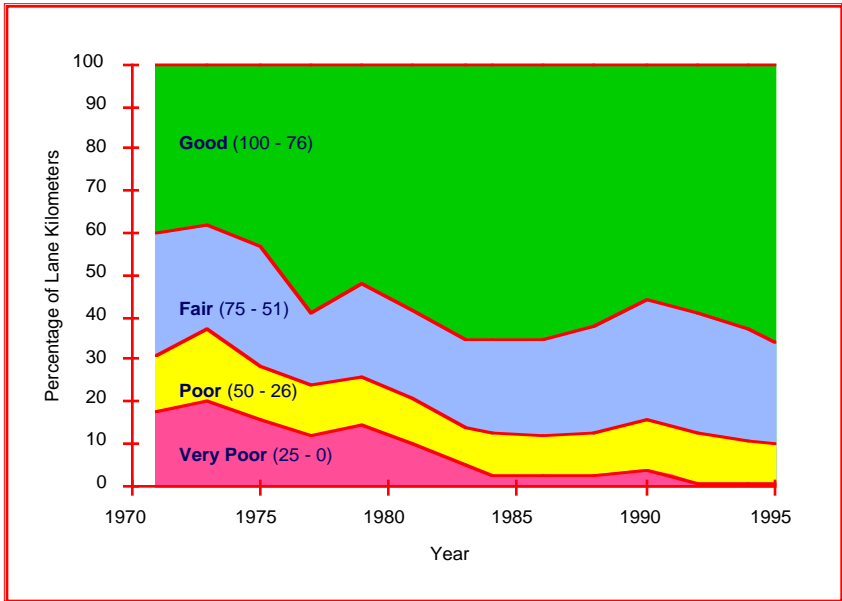
Pavement Structural Condition



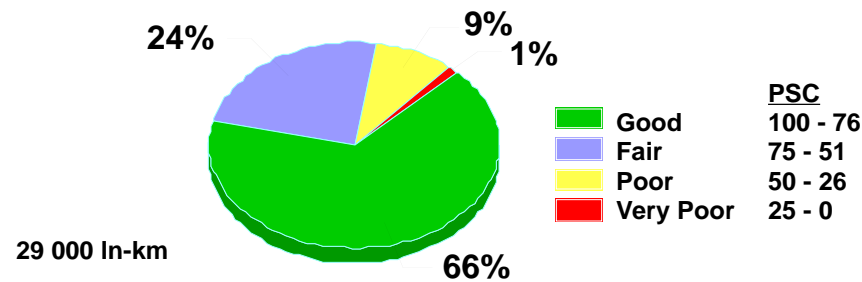
WSDOT attempts to program rehabilitation for pavement segments when they are projected to reach a PSC of 50. A PSC of 50 can occur due to various amounts and severities of distress. For example, a flexible pavement PSC of 50 is calculated when the wheeltrack has 25 percent of the length of the pavement segment experiencing fatigue cracking with "hairline" crack severity (this would represent the earliest stage of major structural deterioration). For rigid pavement, a PSC of 50 represents 50 percent of the PCC slabs exhibiting joint faulting with a severity of 3.2 to 6.4 mm (faulting is the elevation difference at slab joints and results in an extremely rough ride — particularly in large trucks). Further, a PSC of 50 can also be obtained if 25 percent of PCC slabs exhibit 2 to 3 cracks per panel.

Two illustrations show PSC data for the WSDOT route system. For all route classifications (Interstate, Principal Arterial, Minor Arterial, and Major Collector), the overall PSC summarized into the four PSC categories are shown from 1971 to 1995. It is notable how this condition measure has improved over the last 24 years — noteworthy is the reduction of those pavements being in the very poor category from about 20 percent of the total lane-kilometers in the early 1970s down to about one percent in 1995. The adjacent illustration shows the PSC breakout for the 1995 survey year.

PSC Ranges — All WSDOT Routes

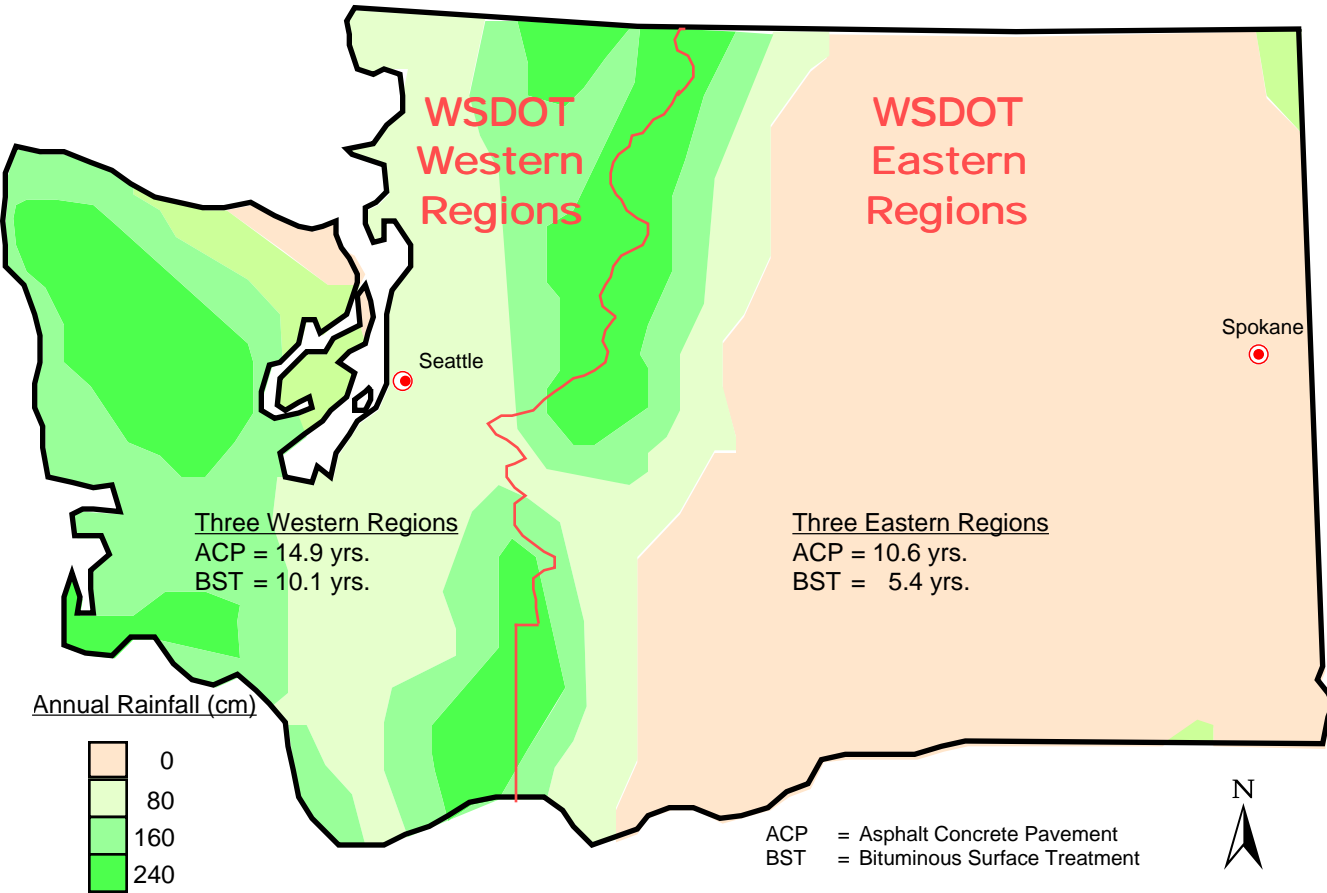


Pavement Structural Condition — All WSDOT Routes — 1995



Using projections to a PSC of 50, the average time to reach that level, which represents a measure of pavement life, varies somewhat between western and eastern Washington. These statistics are shown in the illustration. A primary reason for such differences involves the more severe climate of eastern Washington. This includes the ground freezing and thawing, as well as warmer summertime temperatures.

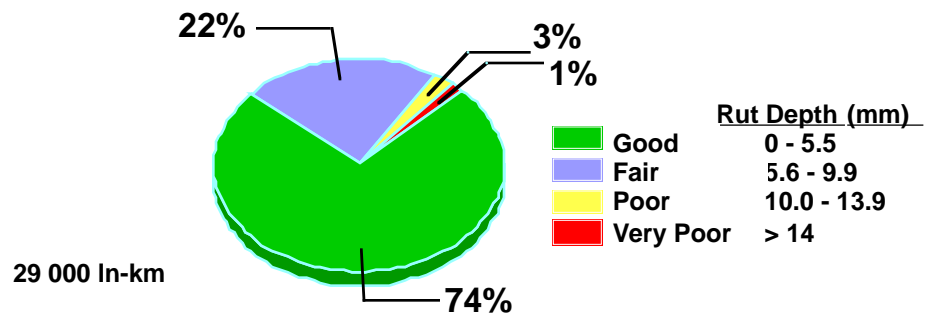
WSDOT Average Pavement Lives — All Routes



Rutting Condition

A second condition measure is pavement rutting. This measure is used to estimate the depth of rutting or depressions in the wheelpaths due to heavy traffic or studded tire wear. Ruts much greater than 14 mm generally have standing water in the wheelpaths — a condition which can be hazardous for high speed traffic. The figure shows the distribution of rutting for all of WSDOT's 29 000 lane-kilometers.

Pavement Rutting Condition — All WSDOT Routes — 1995



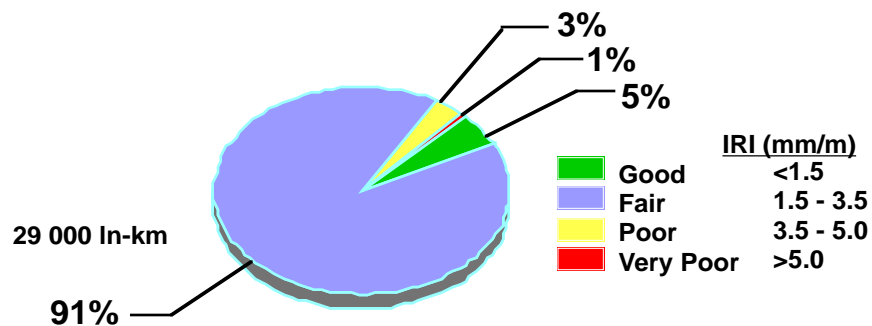
Roughness Condition

Pavement roughness is defined by the International Roughness Index (IRI). The IRI is calculated based on a measured road profile (WSDOT measures these profiles with ultrasonic sensors mounted on a van — the sensors are essentially industrial strength ranging sensors similar to those used in Polaroid cameras). The units of IRI are mm/m. The following IRI ranges are used to define condition categories:

Pavement Roughness IRI Range (mm/m)	Category	Typical Condition
Less than 1.5	Good	Smooth pavements
1.5-3.5	Fair	Modest roughness; upper value noticeable to motorists
3.5-5.0	Poor	Older pavements, roughness quite noticeable; uncomfortable to truck drivers
Greater than 5.0	Very Poor	Very rough pavement, uncomfortable to all motorists

The figure shows the IRI categories for the 1995 survey. WSDOT has been fairly successful in maintaining a relatively smooth route system as the percentages suggest. This is due, in part, to addressing pavement defects (such as cracking) early in their cycle, thus preventing significant roughness from occurring.

International Roughness Index — All WSDOT Routes — 1995



Surface Friction Condition

Surface friction is measured on the complete WSDOT route system every two years. In essence, a coefficient of friction is measured via a locked wheel towed trailer (the actual value is called Friction Number). The friction of most dry pavements is high. Wet pavements are the problem. Thus, the Friction Number testing process involves application of water to the pavement surface prior to determination of the friction value. Such data allows WSDOT to identify and correct very low friction pavements.

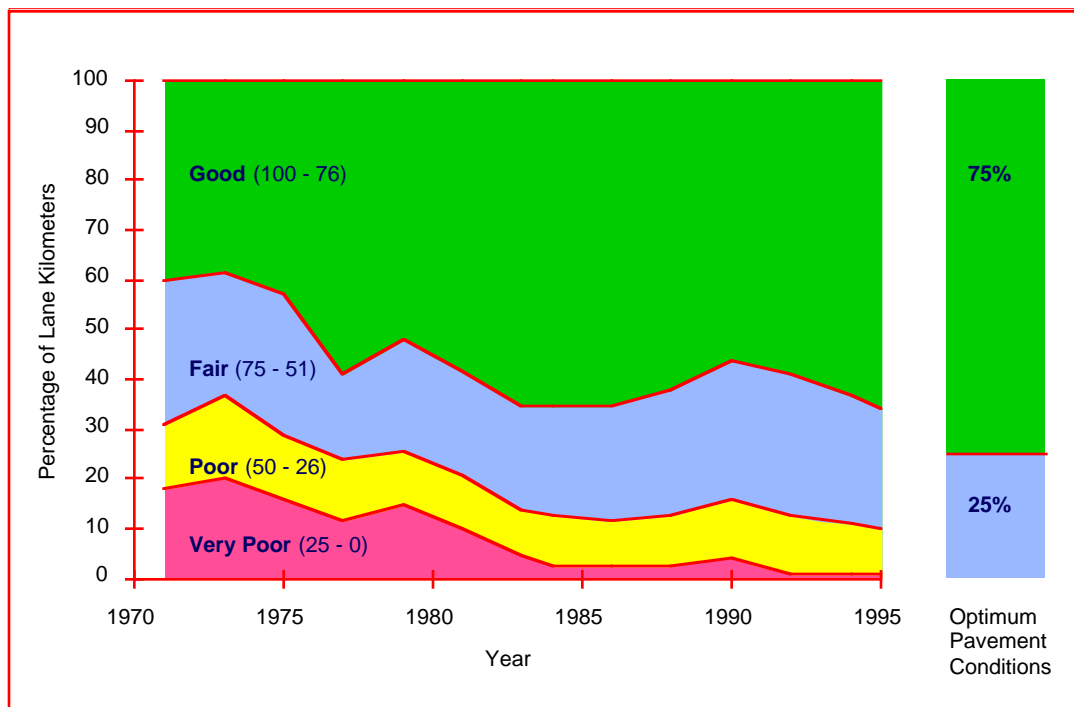
WSDOT Pavement Management

All of the previously described data plus information such as prior contracts, traffic estimates, etc. are incorporated into the WSDOT Pavement Management System (WSPMS). This system has evolved over a period of about 25 years. The primary purpose of the WSPMS is to aid both Regional and Headquarters personnel in managing the pavement structures on the WSDOT route system. Basically, the system helps to determine

- *which* pavements require rehabilitation,
- *when* a specific pavement should be rehabilitated, and
- the approximate *level* (or *amount*) of rehabilitation required.

The fundamental tool used in the WSPMS is illustrated in the adjacent figure and involves the use of "performance curves." Essentially, this process involves plotting actual performance data (such as PSC) versus time for each unique pavement segment on the route system. When, for example, the PSC equals 50, this is the time which results in the optimum application of a rehabilitation treatment (i.e., the lowest life-cycle cost). Such treatments often involve relatively thin asphalt concrete overlays or bituminous surface treatments. The figure shows an average statewide performance curve for asphalt concrete. It also can be used to illustrate how the PSC gradually decreases early in the life of the pavement (initial five years after paving), then deteriorates more quickly as the pavement ages. The overall condition drops quickly for the same time period after the PSC drops below 50.

The "optimum" manner for maintaining the WSDOT route system is to have about 75 percent of the lane-kilometers in the "good" category and 25 percent in the "fair" category. A modification of an earlier figure illustrates this concept.



Summary

This overview briefly illustrated the manner in which WSDOT has constructed and maintained the state-owned highway system. Even though the system has been well-constructed and maintained, issues remain. For example, much of the Interstate PCCP is approaching or has exceeded 30 years of service since construction. These pavements are near the end of their initial life and will need major rehabilitation or, in some cases, complete reconstruction. Since these pavements are mostly in the urban areas of the Puget Sound region, construction will be expensive and disruptive to traffic flow.

Flexible Pavement Asphalt Concrete Surface Statewide Performance Curve

